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ORGANISMS ASSOCIATED WITH OYSTERS CULTURED IN FLOATING SYSTEMS IN VIRGINIA, USA

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ABSTRACT The number and abundance of macro-faunal taxa was estimated from six floating structures (floats) used to culture the Eastern oyster (*Crassostrea virginica*) near Chincoteague Island, Virginia, USA. After a 10-mo grow-out period, all organisms found among and attached to the cultured oysters were counted. The final mean size of oysters was 80.5 (14.7 SD) mm. Overall, 45 species of macrofauna were recorded with the number of species in the floats ranging from 24 to 36. There was no relationship between the number of taxa and the density of oysters in the floats. Total abundances of associated organisms were estimated at 12,746/float to 92,602/float. These findings highlight the diverse (taxonomic and trophic) and abundant nature of communities associated with cultured oysters. They also provide a baseline set of information that may help more clearly define the interactions between oyster culture and the environment.

KEY WORDS: *Crassostrea, virginica*, oysters, aquaculture, epifauna, floats

INTRODUCTION

A consequence of declining wild Eastern oyster (*Crassosotrea virginica*) stocks throughout the eastern seaboard of the United States (MacKenzie et al. 1997) has been concerted efforts focused on oyster restoration (see Luckenbach et al. 1999a). Shellfish restoration throughout the United States is driven by a number of motives (e.g., ecological and fishery value) and typically involves a wide range of user groups (da Silvo Pinho 2000, Breitburg et al. 2000, Brumbaugh et al. 2000, Mann 2000). One approach in support of shellfish restoration is the promotion of aquaculture (mostly of oysters) with the ultimate goal of reducing fishing pressure on wild stocks. During the culture process, oysters are subject to colonization by a variety of organisms. However, the number and relative abundances of taxa associated with the cultured oysters has rarely been assessed, as is the influence of the culture activity on the surrounding habitat. The primary goals of this study are, to identify and enumerate the number of taxa (macro-fauna >2 mm in size) associated with oysters (under culture conditions in Virginia) and to quantify the relative proportions of each taxa. Furthermore, it is hoped that these data will help define any ecological and environmental associations of oysters under culture conditions.

MATERIALS AND METHODS

Oyster culture in Virginia has three distinct stages. The first involves broodstock conditioning, spawning, larval culture, settlement, and an early nursery phase that is effected in a land-based hatchery. Upon removal from the hatchery, a field nursery phase follows where the oysters (3-mm shell height) are placed in mesh bags (2500 oysters per 61 cm × 61 cm bag, 1.5 mm mesh size). As the oysters increase in size, they are stocked in bags with increasingly larger mesh sizes (e.g., 1.5 mm to 3 mm to 9 mm bags) with a concomitant decrease in densities (2500 to 1200 to 600 or less oysters per bag, respectively). The majority of this nursery phase is conducted in off-bottom floating structures called oyster floats (Luckenbach et al. 1999b). The third phase or grow-out phase is conducted either in tray structures located on or near the bottom of the leased area or in floats. The floats most commonly used are mesh baskets (mesh size = 2.54 cm) that are 2.5 mL × 0.6 m W × 0.3 m D. A polyvinyl chloride (PVC, 10 cm in diameter) collar is secured around the open part of the basket providing floatation for the system. A shade cloth cover is stretched over the top of the float to reduce algal fouling and predation of the single oysters in the floats from birds and mammals (e.g., seagulls and otters). Typically, the oysters are emptied directly into the float for final grow-out (1200–1400 oysters per float). This reduces maintenance associated with tending bags and reduces potential growth restrictions on the oysters, a consequence of confinement within bags. Grow-out typically extends from 8–14 mo. During this period, although the aquaculturist may remove the floats from the water to remove dead oysters, the oysters remain undisturbed until they are harvested.

Oysters for this study were cultured at a polyhaline site south (1 km) of Chincoteague Island, Virginia. In May 1998, oysters were removed from the hatchery at a mean shell height of 3 mm and as part of a field nursery phase were grown as outlined earlier. The grow-out phase commenced early September 1998. As part of another study, examining the effect of differential stocking densities on growth in the floats, three floats were initially stocked with 1750 oysters per float and three with 1000 oysters per float. Dead oysters were removed from the floats twice during the grow-out period (November 1998 and April 1999). After approximately 10 mo (mid June 1999), when it was expected that many of the oysters would be harvestable (at 76-mm shell height), sampling of the oysters and associated fauna took place.

Prior to removal of the floats from the water, a mesh basket (capture basket: 2-mm mesh size) was carefully placed in the water surrounding each float and the capture basket and float were loaded onto the support vessel. The purpose of the exterior basket was to retain any motile fauna that passed through the larger mesh of the float. All motile organisms captured on the exterior basket and located within the float were identified and enumerated. Sampling was effected by blindly selecting 50 oysters from all oysters (within each float) laid out in trays on the deck of the vessel. The shell height and width was measured for each randomly collected oyster. In addition, all attached faunal organisms were identified and enumerated. Colonial species were enumerated as a single

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representative of that organism. Total counts of live oysters in the floats were also calculated, thus allowing us to standardize the abundance of organisms in the float.

RESULTS

The final density of oysters cultured in the floats varied considerably and ranged from 488–1381 oysters per float, with an overall mean of 974 oysters per float (Table 1). The density disparity was most likely due to a combination of error associated with original stocking density and differential mortality of oysters in the floats. However, there was little relationship ($r^2 = 0.182$, $P > 0.05$) between oyster density and the number of taxa found in the floats (Fig. 1A). There was a slightly stronger relationship ($r^2 = 0.238$, $P > 0.05$) between the oyster density and the abundance of organisms in the float (see Fig. 1B). Shell height of oysters in the floats ranged from 76.17 to 83.52 mm, with an overall mean of 80.50 mm (see Table 1). The number of macrofaunal taxa in each float ranged from 24 to 36 with an overall mean of 29. In total, 45 faunal taxa were found in the oyster floats (Tables 1 and 2). These represented 11 broad taxonomic groups (see Table 2). The most abundant taxonomic group was annelids that comprised from 47.44% to 69.37% of organisms in the six floats. Mollusks comprised the next most abundant group (11.45% to 27.93%) followed by crustaceans (11.49% to 15.73%). Overall, in terms of abundance, annelids comprised 57.64% of all organisms, mollusks 20.01% and crustaceans 13.76% (see Table 2). These groups comprised 91.4% of all organisms sampled from the floats.

DISCUSSION

The total number of taxa (45) found among the oysters in this study was relatively high and compare favorably with the findings of previous studies of oyster communities (Wells 1961, Bahr 1974, Dame 1979, Larsen 1985, Stanley & Sellers 1986, Zimmerman et al. 1989). Meyer and Townsend (2000) recorded 41 species associated with newly constructed oyster reefs in North Carolina. However, many of these authors report on open reef structures relying on natural recruitment of oysters in mesohaline environments. Given the polyhaline character of the Chincoteague site used in this study it might be expected that the number of taxa recorded would be higher. That greater numbers of taxa were not recorded is likely a consequence of the fact that the assessment of associated organisms was carried out after only 10 months of potential colonization time in an enclosed structure suspended in the water column. In addition, this limited colonization time may have some bearing on the fact that certain species, typically associated with oysters in similar environments (e.g., the boring sponge, *Cliona celata*) were not recorded in this study.

TABLE 1.

Final individual and overall parameter values calculated for oysters and associated organisms in the culture floats.

	Oyster Density	Height Mean-mm (SD)	Width Mean-mm (SD)	Number of Taxa	Estimated Abundance
	806	80.98 (14.15)	52.23 (6.29)	29	20,501
	488	80.43 (11.62)	52.33 (8.03)	30	12,746
	749	79.48 (12.20)	51.46 (8.03)	24	28,132
	1363	76.17 (19.56)	47.29 (10.18)	36	92,602
	1004	82.42 (14.54)	51.97 (5.25)	25	32,449
	1381	83.52 (16.55)	51.66 (7.63)	29	36,044
Overall means	974	80.50 (14.65)	51.15 (7.62)	~29	37,079

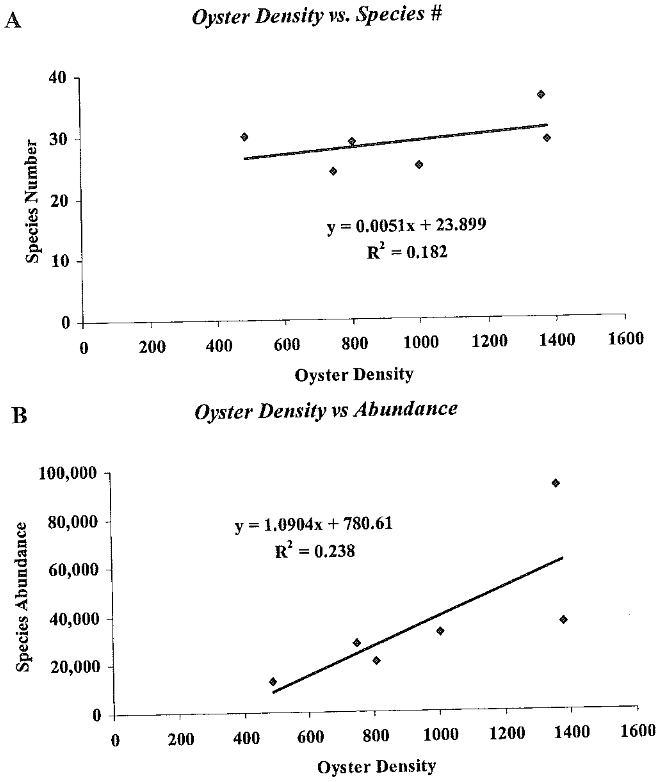

Figure 1. Overall macrofaunal species number plotted against oyster density (A) and overall species abundances plotted against oyster density, in the culture systems (B).

Palmer et al. (1998) observed that little baseline data are available to serve as guidelines for restoring aquatic habitats. Not the least of these is species composition, from which community structure and trophic interactions may be evaluated. From our findings, a number of trophic groups are apparent in the culture systems. While filter feeders dominated (bivalves), others represented were detritivores (e.g., *Polydora websteri, Palaemonetes vulgaris*, omnivores (e.g., *Gobiosoma bosci*) and carnivores (e.g., *Callinectes sapidus*). The diversity of feeding types suggests the potential for various trophic interactions within the culture system and between the system and the surrounding habitat. Of course, limitations are imposed on the interactions by the meshing that comprises the floats. For example, larger predators (e.g., mature blue crabs, fishes, etc.) may be excluded. A potential limitation in interpreting the results of this study, imposed by the sampling methodology, is that smaller motile species (e.g., amphipods) may not have been retained by the 2-mm sampling mesh.

The dominance (in terms of abundance) of relatively few taxa is not unusual for shellfish assemblages. In this study, 3 groups of organisms (polychaetes, crustaceans, and mollusks) comprised 91.4% of all of the macrofauna sampled. Tenore and Gonzalez. (1975) observed that dense epifaunal assemblages (dominated by few taxa) were associated with cultured mussels in Spain. For wild oyster populations, O'Beirn (unpublished data) documented that numerically 94.6% of all faunal organisms found on a constructed oyster reef in Virginia were represented by four taxa. Seed and Suchanek (1992) and Lintas and Seed (1994) had similar findings

TABLE 2.

Relative proportions of organisms sampled in oyster culture floats used in this study and overall means of proportions for each taxa.

			Float					
		Overall Mean	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**
Porifera								
Cliona celata	Boring sponge	0.15		0.22	0.18	0.05	0.17	0.62
Halichondria bowerbanki	Bread sponge	0.81	0.08	0.33	1.07	1.06	0.59	1.09
Lissodendoryx sp.	Garlic sponge	0.06		0.33				0.31
Microciona prolifera	Red beard sponge	0.07			0.18		0.08	0.31
Cnidaria								
Actinaria spp.	Anemones	2.50	0.31	0.89	0.09	4.55	0.08	4.52
Hydroida		3.16	2.59	4.12	3.28	2.90	3.29	3.90
Platyhelminthes								
Stylochus ellipticus	Flatworm	<0.01		0.01				
Annelida								
Hydroides dianthus	Fan-worm	25.99	24.69	20.28	28.84	24.19	33.96	22.93
Lepidonotus sp.	Scale worm	<0.01	0.01	0.01		0.01		
Polydora websteri	Spionid-worm	<0.01	0.01	0.01			0.01	0.01
Sabella micropthalma	Fan worm	1.32	0.39	0.22	0.71	2.71	0.25	0.31
Sabellaria sp.	Mason worm	0.26			0.18			2.03
Spirorbis sp.	Spirobid worms	29.88	34.44	32.53	39.76	26.58	31.93	22.15
Crustacea								
Balanus eburneus	Barnacle	11.46	12.74	10.58	8.08	12.83	12.50	7.64
Callinectes sapidus	Blue crab	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cronius ruber	Red crab	<0.01	0.01	0.01		0.01		
Dyspanopeus sayi	Mud crab	0.16	0.20	0.21	0.30	0.10	0.16	0.16
Eurypanopeus depressus	Mud crab	0.02	<0.01	0.01	0.01	0.03	0.01	0.01
Hemigrapsus sanguineus	Asian shore crab	<0.01	<0.01					
Lysmata wurdermanni	Peppermint shrimp	<0.01				<0.01		
Palaemonetes vulgaris	Grass shrimp	1.73	0.27	4.33	3.61	1.43	0.52	2.99
Xanthidae spp.	Xanthid crabs	0.12		0.23	0.20	0.04	0.28	0.18
Panopeus herbstii	Mud crab	0.26	0.21	0.35	0.33	0.17	0.28	0.50
Mollusca								
Anadara ovalis	Blood ark	0.01		0.11				
Anadara transversa	Transverse ark	0.02				0.05		
Anomia simplex	Common jingle	3.77	2.75	4.90	1.60	3.77	2.53	8.11
Crassostrea virginica	Eastern oyster	15.47	18.95	16.49	9.76	16.83	11.49	17.16
Crepidula fornicata	Slipper shell	0.20	0.31	0.11	0.09	0.28	0.08	0.16
Crepidula plana	Slipper shell	0.49	0.08	0.56		0.41		2.34
Doris verrucosa	Nudibranch	<0.01		0.01		<0.01		
Mytilus edulis	Blue mussel	0.04		0.11		0.05		0.16
Urosalpinx cinerea	Oyster drill	<0.01					<0.01	
Bryozoa								
Membranipora tenuis	Encrusting bryozoan	1.30	1.10	1.45	1.24	1.38	0.93	1.72
Echinodermata								
Arbacia punctulata	Purple sea urchin	<0.01				<0.01		
Tunicata								
Aplidium stellatum	Sea pork	0.06	0.08	0.56				0.16
Didemnum sp.	Paintsplash tunicate	0.05	0.08			0.05		0.16
Mogula manhattensis	Sea squirt	0.09	0.08	0.67	0.18	0.05		
Styela plicata	Rough sea squirt	0.16	0.16	0.33		0.14	0.17	0.31
Pisces								
Chasmodes bosquianus	Striped blenny	<0.01	0.02			<0.01		
Fundulus heteroclitus	Mummichog	0.13	0.09		0.16	0.07	0.43	0.05
Gobiosoma bosci	Naked goby	0.02	0.03			0.04	0.01	
Gobiesox strumosus	Skilletfish	0.01	0.02		0.01	0.01	<0.01	
Opsanus tau	Oyster toad fish	<0.01				<0.01		
Hypsoblennius hentzi	Feather blenny	0.18	0.28	0.01	0.14	0.23	0.22	0.01
Tautoga onitis	Tautog	<0.01				<0.01		

for faunal communities associated with the blue mussel, *Mytilus edulis*. It must be noted that, whereas numerical dominance (as assessed in this study) may be a useful indicator of community composition, species biomass (not assessed in this study) may yield different conclusions regarding community structure that may be equally as important.

The occurrence of some species in the floats is of particular interest. The portunid crab, *Cronius ruber*, was considered rare in

Virginia (Van Engel & Sandifer 1972). However, in this study, five specimens, ranging in size from 24.9–34.9 mm, were located within the floats. These findings allied with previous and subsequent observations (O'Beirn personal observation), suggest that they are more than just occasional or rarely occurring species. The numerous fish species sampled highlight the importance of oysters as habitat for these species. Not only is the interstitial space among the oysters important, but dead articulated shells also provide useful habitat (in the form of refuge or nesting sites) for the blennies and gobies (Breitburg 1999).

The increase in aquaculture activities throughout the world has initiated much discussion and research on the interaction between the activity and the environment (Freeman 1988, Hickey & Hurst 1989, Iwama 1991, Hastings & Heinle 1995). Oysters may be cultured in areas that were previously devoid of the species. Hence, they could be regarded as an introduced species into a system. Simenstad and Fresh (1995) recommend that resource managers should consider the effects of aquaculture and attendant activities on ecosystem and community levels. The effects of introducing a large-scale monospecific culture operation into a particular system can have a cascading effect and ultimately affect production and the species composition inherent within the system (Simenstad & Fresh 1995). A shift in the ecological balance may affect the ability of the communities within the system to withstand perturbations of one form or another.

It has been suggested that shellfish culture activities benefit the environment by attracting numerous other organisms to the area (Dewey 2000). Whether they are truly an ecological or environmental benefit or not has yet to be specifically determined. The benefits (i.e., habitat and production) afforded by oyster culture activities may be minimal given the ephemeral nature of these communities (mediated by harvest and handling schedules). Many organisms constituting these communities may not actually mature to reproduce. Consequently, these systems may be regarded as sink populations. In addition, certain associated species may actually compete with the culture organism for food resources (e.g., blue mussels and wild oysters setting on the cultured oysters; Adams et al. 1991), and increase the organic loading emanating from the culture systems (Nugues et al. 1996). Finally, as urbanization and human activities lead to an increase in habitat alteration in coastal areas (Connell 2000), suites of potentially competing organisms may be introduced into an area. Such a phenomenon may upset the ecologic balance of the area by changing the constituent organisms and species interactions within the system. As the scale of anthropogenic activities increase, it will be increasingly important to further elucidate these and other ecologic interactions.

A major impediment to successful restoration of impacted shellfish habitats is defining success of a particular venture (Coen & Luckenbach 2000). Defining goals and establishing success criteria has proven difficult, given that in many regions natural shellfish habitats (to use as reference locations) are lacking (Luckenbach et al. 1999a, and references therein). Anecdotal accounts of shellfish population structure and associated organisms in particular regions most often are insufficient upon which to base an expensive and long-term restoration program. Therefore, these data may give an indication (in terms of community assemblage and/or trophic interactions) of what may be expected when initiating an oyster restoration program.

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